Chapter 2
MANUFACTURING OPERATIONS

REVIEW QUESTIONS

2.1 What is manufacturing?

Answer: Two definitions are given in the text. The technological definition is the following: Manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products. Manufacturing also includes the joining of multiple parts to make assembled products. The economic definition is the following: Manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations.

2.2 What are the three basic industry categories?

Answer: The three basic industry categories are (1) primary industries, which are those that cultivate and exploit natural resources, such as agriculture and mining; (2) secondary industries, which convert the outputs of the primary industries into products; they include manufacturing, construction, and power generation; and (3) tertiary industries, which constitute the service sector of the economy; examples include banking, retail, transportation, education, government.

2.3 What is the difference between consumer goods and capital goods?

Answer: Consumer goods are products that are purchased directly by consumers, such as cars, personal computers, TVs, tires, toys, and tennis rackets. Capital goods are products purchased by other companies to produce goods and supply services. Examples include commercial aircraft, mainframe computers, machine tools, railroad equipment, and construction machinery.

2.4 What is the difference between a processing operation and an assembly operation?

Answer: A processing operation transforms a work material from one state of completion to a more advanced state that is closer to the final desired part or product. It adds value by changing the geometry, properties, or appearance of the starting material. An assembly operation joins two or more components to create a new entity, called an assembly, subassembly, or some other term that refers to the joining process.

2.5 Name the four categories of part-shaping operations, based on the state of the starting work material.

Answer: The four categories are (1) solidification processes, (2) particulate processing, (3) deformation processes, and (4) material removal processes.

2.6 Assembly operations can be classified as permanent joining methods and mechanical assembly. What are the four types of permanent joining methods?

Answer: The joining processes are (1) welding, (2) brazing, (3) soldering, and (4) adhesive bonding.

2.7 What is the difference between hard product variety and soft product variety?

Answer: Hard product variety is when the products differ substantially. In an assembled product, hard variety is characterized by a low proportion of common parts among the

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products; in many cases, there are no common parts. Soft product variety is when there are only small differences between products. There is a high proportion of common parts among assembled products whose variety is soft.

2.8 What type of production does a job shop perform?

Answer: Low production of specialized and customized products. The products are typically complex, such as experimental aircraft and special machinery.

2.9 Flow line production is associated with which one of the following layout types: (a) cellular layout, (b) fixed-position layout, (c) process layout, or (d) product layout?

Answer: (d) Product layout.

2.10 What is the difference between a single-model production line and a mixed-model production line?

Answer: A single-model production line makes products that are all identical. A mixed-model production line makes products that have model variations characterized as soft product variety.

2.11 What is meant by the term *technological processing capability*?

Answer: Technological processing capability of a plant (or company) is its available set of manufacturing processes. It includes not only the physical processes, but also the expertise possessed by plant personnel in these processing technologies.

PROBLEMS

Answers to problems labeled **(A)** are listed in the Appendix at the back of the book.

2.1 **(A)** A manufacturing plant produces three product lines in one of its plants: A, B, and C. Each product line has multiple models: 3 models within product line A, 5 models within B, and 7 within C. Average annual production quantities of model A is 400 units, 800 units for model B, and 500 units for model C. Determine the number of (a) different product models and (b) total quantity of products produced annually in this plant.

Solution: (a) The total number of different product models produced is
$P = 3 + 5 + 7 =$ **15 different models**

(b) The total production quantity of all products made in the factory is
$Q_f = 3(400) + 5(800) + 7(500) = 1200 + 4000 + 3500 =$ **8700 units** annually

2.2 Consider product line A in preceding Problem 2.1. Its three models have an average of 46 components each, and the average number of operations needed to produce each component is 3.5. All components are made in the same plant. Determine the total number of (a) components produced and (b) operations performed in the plant annually.

Solution: (a) The total number of components produced is given by Eq. (2.7).
$n_{pf} = PQn_p = 3(400)(46) =$ **55,200 components**

(b) The total number of operations performed annually in the plant is given by Eq. (2.9).
$n_{of} = PQn_pn_o = 3(400)(46)(3.5) =$ **193,200 operations**

2.3 A company produces two products in one of its plants: A and B. Annual production of Product A is 3600 units and of Product B is 2500 units. Product A has 47 components and Product B has 52 components. For Product A, 40% of the components are made in the plant, while 60% are purchased parts. For Product B, 30% of the components are made in the plant,

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while 70% are purchased. For these two products taken together, what is the total number of (a) components made in the plant and (b) components purchased?

Solution: (a) The total number of components produced in the plant can be determined using Eq. (2.3), adjusting it for the proportions of each part made in the factory: n_{pf} = 3600(47)(0.40) + 2500(52)(0.30) = 67,680 + 39,000 = **106,680 parts made in plant**

(b) Let n_{pp} = the total number of parts purchased: n_{pp} = 3600(47)(0.60) + 2500(52)(0.70) = 101,520 + 91,000 = **192,520 purchased parts**

2.4 **(A)** A product line has two models: X and Y. Model X consists of 4 components: a, b, c, and d. The number of processing operations required to produce these four components are 2, 3, 4, and 5, respectively. Model Y consists of 3 components: e, f, and g. The number of processing operations required to produce these three components are, 6, 7, and 8 respectively. The annual quantity of Model X is 1000 units and of Model Y is 1500 units. Determine the total number of (a) components and (b) processing operations associated with these two models.

Solution: (a) The total number of components can be determined using Eq. (2.3): n_{pf} = 1000(4) + 1500(3) = 4000 + 4500 = **8500 components**

Alternatively, Eq. (2.7) can be used, first computing the average values for Q and n_p using Eqs. (2.6) and (2.8).
Q = (1000 + 1500)/2 = 1250 units
n_p = (1000(4) + 1500(3))/(2 × 1250) = 3.4 components per unit product
n_{pf} = 2(1250)(3.4) = 8500 components

(b) The total number of processing operations can be determined using Eq. (2.4): n_{of} = 1000(2 + 3 + 4 + 5) + 1500(6 + 7 + 8) = 1000(14) + 1500(21) = **45,500 operations**

Alternatively, Eq. (2.9) can be used, first computing the average values for n_p and n_o using Eqs. (2.8) and (2.10).
The value of n_p was calculated above: n_p = 3.4 components per unit product
n_o = (1000(2 + 3 + 4 + 5) + 1500(6 + 7 + 8))/3.4 = 5.353 operations per component
n_{of} = 2(1250)(3.4)(5.353) = 45,500 operations

2.5 The ABC Company is planning a new product line and a new plant to produce the parts for the line. The product line will include 8 different models. Annual production of each model is expected to be 900 units. Each product will be assembled of 180 components. All processing of parts will be accomplished in the new plant. On average, 6 processing operations are required to produce each component, and each operation takes an average of 1.0 min (including an allowance for setup time and part handling). All processing operations are performed at workstations, each of which includes a production machine and a human worker. The plant operates one shift. Determine the number of (a) components, (b) processing operations, and (c) workers that will be needed to accomplish the processing operations if each worker works 2000 hr/yr.

Solution: (a) Number of components produced in the plant:
$n_{pf} = PQn_p =$ 8(900)(180) = **1,296,000 components**

(b) Number of operations performed in the plant:
$n_{of} = PQn_pn_o$ = 8(900)(180)(6) = **7,776,000 operations** in the plant per year

(c) Total operation time $TT = n_{of}T_p$, where T_p = time for one processing operation.
TT = 7,776,000(1.0) = 7,776,000 min = 129,600 hr of processing time

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At 2000 hours/yr per worker, number of workers w = 129,600/2000 = 64.8 workers
This should be rounded up to **65 workers**.

2.6 The XYZ Company is planning a new product line and a new factory to produce the parts and assembly the final products. The product line will include 10 different models. Annual production of each model is expected to be 1000 units. Each product will be assembled of 300 components, but 65% of these will be purchased parts (not made in the new factory). There are an average of 8 processing operations required to produce each component, and each processing step takes 30 sec (including an allowance for setup time and part handling). Each final unit of product takes 48 min to assemble. All processing operations are performed at work cells that include a production machine and a human worker. Products are assembled at single workstations consisting of one worker each plus assembly fixtures and tooling. Each work cell and each workstation require 25 m^2 of floor space and an additional allowance of 45% must be added to the total production area for aisles, work-in-process storage, shipping and receiving, rest rooms, and other utility space. The factory will operate one shift (the day shift, 2000 hr/yr). Determine (a) how many processing and assembly operations, (b) how many workers (direct labor only), and (c) how much total floor space will be required in the plant.

Solution: (a) The number of products is $Q_f = PQ$ = 10(1000) = 10,000 products/yr
Therefore, the number of final assembly operations = **10,000 asby ops/yr**
Total number of parts n_{pf} = 10(1000)(300) = 3,000,000 components, but 65% of these are purchased, so the number made in the plant will be 0.35(3,000,000) = 1,050,000
Number of processing operations n_{of} = 1,050,000(8) = **8,400,000 proc ops/yr**

(b) Total processing time $TT_p = n_{of}T_p$, where T_p = time for one processing operation.
TT_p = 8,400,000(0.50) = 4,200,000 min = 70,000 hr/yr
Total assembly time $TT_a = QT_a$, where T_a = assembly time for each product.
TT_a = 10,000(48) = 480,000 min/yr = 8000 hr/yr
Number of workers w = (70,000 + 8000)/2000 = **39 workers**

(c) With 1 worker per workstation for processing operations and 1 worker per assembly workstation, $n = w$ = 39 workstations.
Total floor space $TA = nA_w(1 + AL)$, where A_w = area of each work cell or workstation, and AL = allowance for aisles, storage, etc.
TA = 39(25)(1 + 0.45) = **1413.75 m^2** (~15,217 ft^2)

2.7 Suppose the company in Problem 2.6 were to operate two shifts (a day shift and an evening shift, a total of 4000 hr/yr) instead of one shift to accomplish the processing operations. The assembly of the product would still be accomplished on the day shift. Determine (a) how many processing and assembly operations, (b) how many workers on each shift (direct labor only), and (c) how much total floor space will be required in the plant.

Solution: (a) Number of final assembly operations PQ = 10(1000) = **10,000 asby ops/yr**
Total number of parts n_{pf} = 10(1000)(300) = 3,000,000 components, but 65% of these are purchased, so the number made in the plant will be 0.35(3,000,000) = 1,050,000
Number of processing operations n_{of} = 1,050,000(8) = **8,400,000 proc ops/yr**

(b) Total processing time $TT_p = n_{of}T_p$, where T_p = time for one processing operation.
TT_p = 8,400,000(0.50 min) = 4,200,000 min = 70,000 hr/yr total for two shifts
TT_p = 70,000/2 = 35,000 hr/yr total for each shift
Number of processing operation workers per shift w_p = 35,000/2000 = 17.5 rounded up to 18 parts production workers per shift

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Total assembly time $TT_a = QT_a$, where T_a = assembly time for each product.
TT_a = 10,000(48) = 480,000 min/yr = 8000 hr/yr
Number of assembly workers w_a = 8000/2000 = 4 assembly workers
Number of workers on day shift w = 18 + 4 = **22 workers**
Number of workers on evening shift w = **18 workers**

(c) The floor space must be based on the number of day shift operations, which includes processing and assembly operations.
Total floor space $TA = nA_w(1 + AL)$, where A_w = area of each work cell or workstation, and AL = allowance for aisles, etc.
TA = 22(25)(1 + 0.45) = **797.5 m²** (~8584 ft²)
Comment: This is a savings in floor space of ~44% compared to the one-shift operation in the previous problem.

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